MATLAB/SIMULINK MODULES FOR MODELING AND SIMULATION OF POWER ELECTRONIC CONVERTERS AND ELECTRIC DRIVES

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by

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2006

Dedicated to

the Loving memory of my parents

Late Prof. P.K. Ramanatha Iyer and Late Smt. P.N. Kavery Ammal

Certificate of Authorship/Originality

I certify that the work presented in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that this thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

P.R. Narayana Swamy.

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LIST OF SYMBOLS

The following are some of the predominant symbols used. The other symbols are explained within the text in the appropriate places.

C - Capacitor in Farads
D - Damping constant
CF - Filter Capacitor in Farads
E - E.M.F. Source
f, fsw - Frequency in Hertz
I, i - Current
J - Moment of Inertia in kg.m^2.
L, L1 - Inductance in Henries
Lm - Mutual Inductance in Henries
P - Number of Poles
R - Resistance in Ohms
SF - Switch Function
SF_BAR - Inverse Switch Function
T - Switching Period
Tem - Electromagnetic torque in Nw-M
Tmech - Mechanical Load Torque
V, v - Voltage
α - Firing angle
ω - Angular frequency in rad per sec
ω_C - Angular frequency of the arbitrary reference frame in rad per sec
ω_S - Angular frequency of the Stationary or Stator reference frame in rad per sec.
ω_r - Angular frequency of the rotor reference frame in rad per sec.
φ - Phase advance angle
θ - Angle the reference frame makes with the stator abc axis.
λ - Flux linkage

ψ - Flux Linkage per second

λm - Rotor Magnet Constant in volt.sec per elec.rad.

ωre - Rotor speed in electrical radians per second

ωrm - Rotor speed in Mechanical radians per second

Suffix:

d - Direct axis

q - Quadrature axis

e - Electrical

m - Mechanical

re - Rotor electrical

c - Arbitrary

s - Stationary or Stator

r - Rotor

a,b,c - Three phase ac A, B, C

r,y,b - Three Phase ac R, Y, B

n -Neutral

L, l - Line

dc - DC Link

ACRONYMS

BJT - Bipolar Junction transistor

CCM - Continuous Conduction Mode

CS - Clipped Sinusoid

DCM - Discontinuous Conduction Mode

DCTLI - Diode Clamped Three Level Inverter

FCTLI - Flying Capacitor Three Level Inverter

FWDBR – Full Wave Diode Bridge Rectifier

FWCBR – Full Wave Controlled Bridge Rectifier

GTO - Gate Turn off Thyristor

HI - Harmonic Injection

IGBT - Insulated gate Bipolar Transistor

MOSFET - Metal Oxide Semiconductor Field Effect Transistor

IM - Induction Motor

OP.AMP. – Operational Amplifier

PMSM - Permanent Magnet Synchronous Motor

PWM - Pulse Width Modulation.

SCR - Silicon Controlled Rectifier

SMPS – Switched Mode Power Supply

THI - Third Harmonic Injection

ABSTRACT

Modelling and simulation of power electronic converters and electric drives play a vital role in the academic curriculum and also in the industry. A number of modelling and simulation tools are used to study the performance of power electronic converters and electric drives. For the analysis and simulation of three phase electric drives, the three (abc) axis to two (dq) axis transformation is used [1]. The results in the dq axis is transformed to abc axis by suitable inverse transformation.

Over the past, several analog, hybrid and digital computers were used for simulation of converter fed electric drives [2, 13, 29, 30, 33, 34, 35]. In the recent years, a number of software packages have been developed to study the performance of power electronic converters and converter fed electric drives [3 - 9].

SIMULINK developed by **Mathworks Inc., USA.** is one of the softwares used for power electronic converters and electric drive simulation [3, 4, 11]. This software is used for modelling the power electronic converters and electric drives discussed in this thesis.

This thesis describes the interactive modelling of power electronic converters such as ac to dc, dc to ac, dc to dc and ac to ac and ac drives such as the three phase IM and Six Step Inverter fed PMSM, using the software SIMULINK. **Unless specified otherwise, the term "model" in this thesis refers to SIMULINK model.** Interactive Library Building Blocks are developed using SIMULINK for the above power electronic converters. These library models are then used to develop PWM converters. The models for well known PWM techniques such as Sine, HI, THI are presented. The interactive model for a totally new PWM technique known as Clipped Sinusoid PWM (CSPWM) is presented in this thesis. Where possible the results are compared with literature references, by theoretically derived formula and also by Electronic Circuit Simulation software..

Abstract

Interactive Circuit Model of a Digital Gate Drive for a Three Phase 180 Degree mode two level inverter using four line to one line multiplexer is presented and the results compared with well known literatures on power electronics and also by experimental verification.

Interactive system Models for three phase ac Line fed IM drive in all reference frames using dq0 voltage – current and flux linkage equations in state space are presented and simulation results compared with the literature references. This is followed by various system models for three phase Pulse Width Modulated Inverter fed IM drive.

Interactive system models for Six Step Continuous and Discontinuous current mode inverter fed PMSM drives are presented and the results are compared experimentally, by theoretically derived formula and also with the literature references.

Interactive system models for Buck Converter Switched Mode Power Supply (SMPS) are given and the results compared with the literature references and also by electronic circuit simulation.

Interactive system models for Three phase DCTLI and FCTLI are presented and the result compared with literature references and also by theoretical derivations.

Harmonic analysis of six step continuous current mode two level inverter and three phase three level inverter are presented in APPENDIX A. Experimental data and MATLAB programs to calculate the parameters of the six step Lybotec inverter fed PMSM drive in the laboratories of CEMPE are presented in APPENDIX B. The block diagram schematic of the six step Lybotec Inverter in the laboratories of CEMPE is provided in APPENDIX C. Some data sheets for selected integrated circuits are provided in APPENDIX D. Comparison of the model performance of Power Electronic Converters and Electric Drives presented in this thesis made with the Electronic Circuit Simulation Software PSIM, MICROCAP8 and the SimPowerSystems Block set of SIMULINK is presented in APPENDIX E. The list of publications from this thesis is given in APPENDIX F..

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